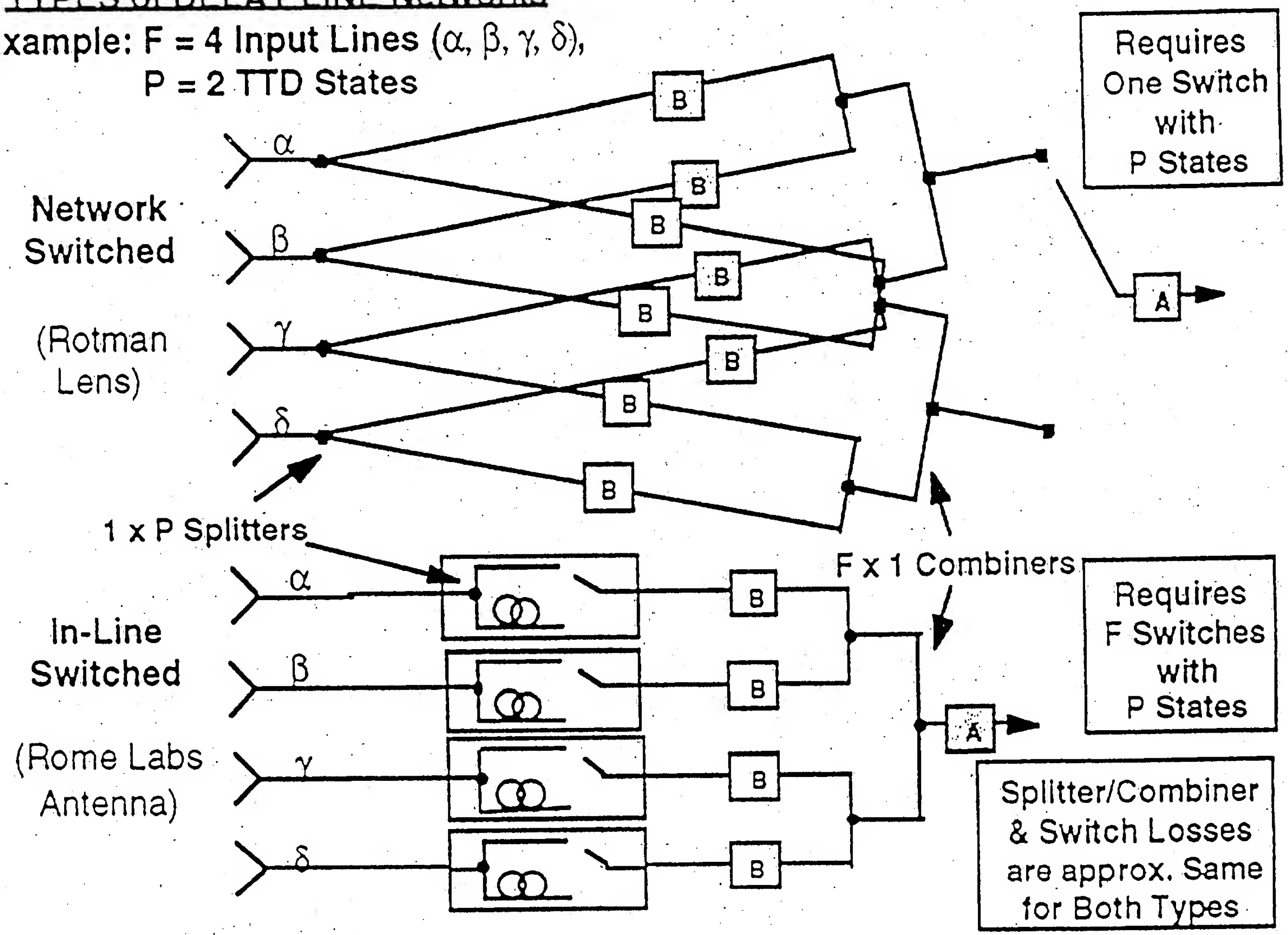
TYPES of DELAY LINE Networks

Example: F = 4 Input Lines ($\alpha, \beta, \gamma, \delta$),
P = 2 TTD States

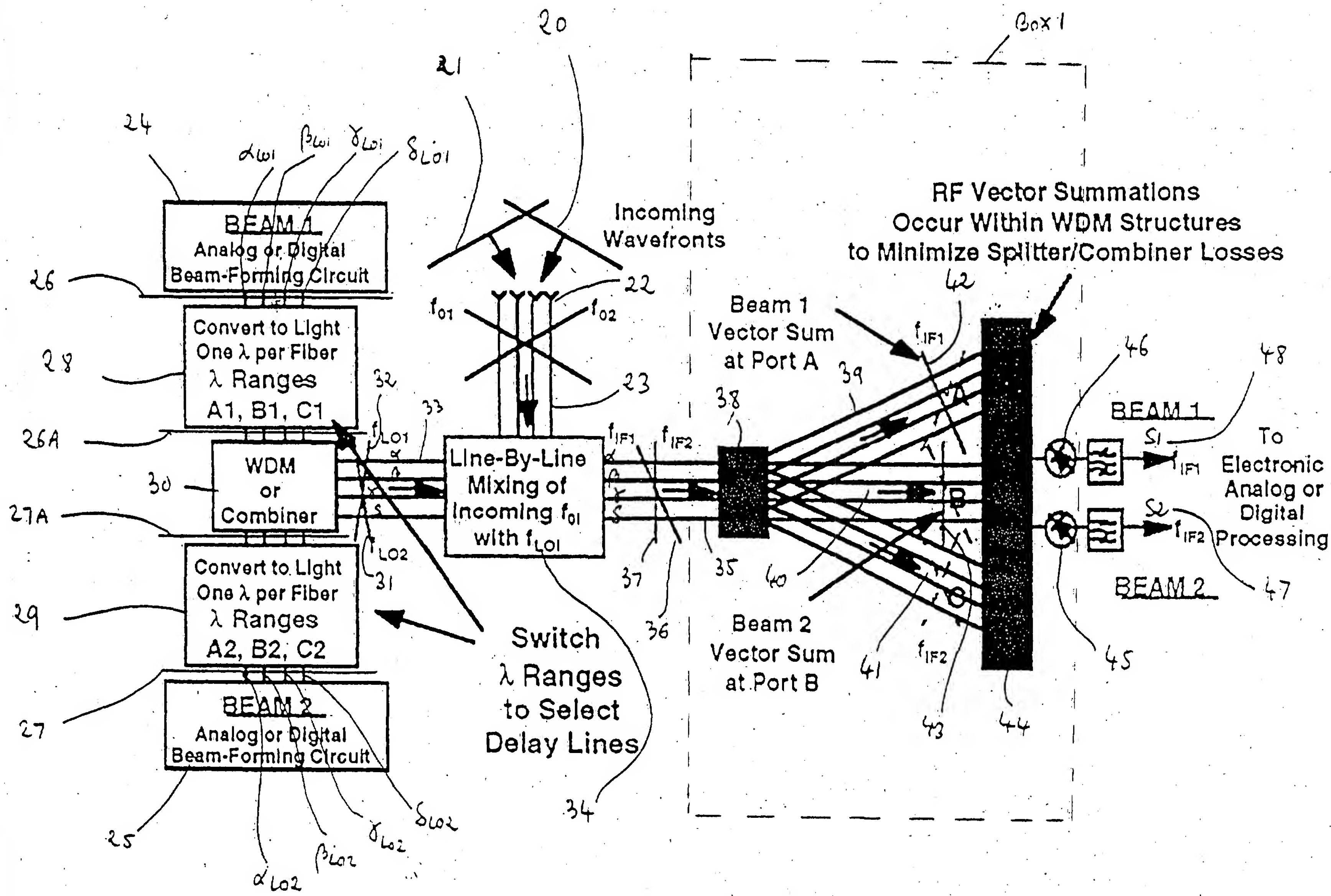
Fig. 1a

Fig 1b



PRIOR ART

EL052826128US
EV258281415US



BEAM 1
Analog or Digital
Beam-Forming Circuit
Convert to Light
One λ per Fiber
λ Ranges
A1, B1, C1
WDM
or
Combiner
Convert to Light
One λ per Fiber
λ Ranges
A2, B2, C2
BEAM 2
Analog or Digital
Beam-Forming Circuit
Incoming
Wavefronts
Line-By-Line
Mixing of
Incoming f_{01}
with f_{LO1}
Switch
λ Ranges
to Select
Delay Lines
Beam 1
Vector Sum
at Port A
Beam 2
Vector Sum
at Port B
RF Vector Summations
Occur Within WDM Structures
to Minimize Splitter/Combiner Losses
BEAM 1
BEAM 2
To
Electronic
Analog or
Digital
Processing
Box 1
f_{01}
f_{02}
f_{LO1}
f_{LO2}
f_{IF1}
f_{IF2}
S_1
S_2
α_{LO1}
β_{LO1}
γ_{LO1}
δ_{LO1}
α_{LO2}
β_{LO2}
γ_{LO2}
δ_{LO2}
A
B
C
20
21
22
23
24
25
26
26A
27
27A
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48

Fig. 2

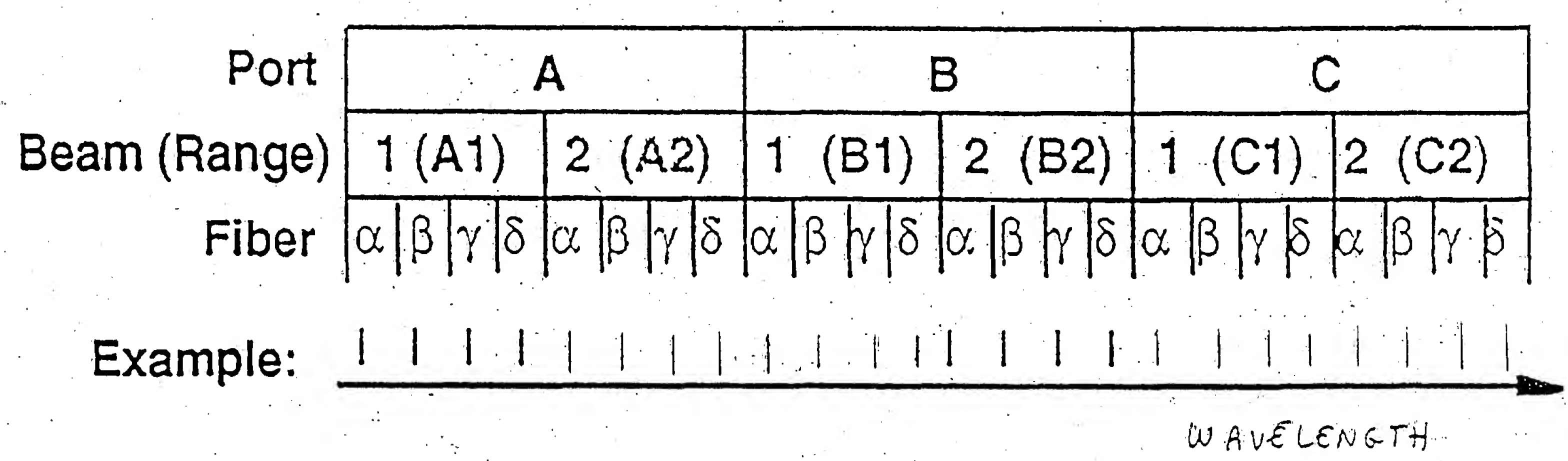

Port
A
B
C
Beam (Range)
1 (A1)
2 (A2)
1 (B1)
2 (B2)
1 (C1)
2 (C2)
Fiber
α β γ δ α β γ δ α β γ δ α β γ δ α β γ δ α β γ δ
Example:
WAVELENGTH

Fig. 3a

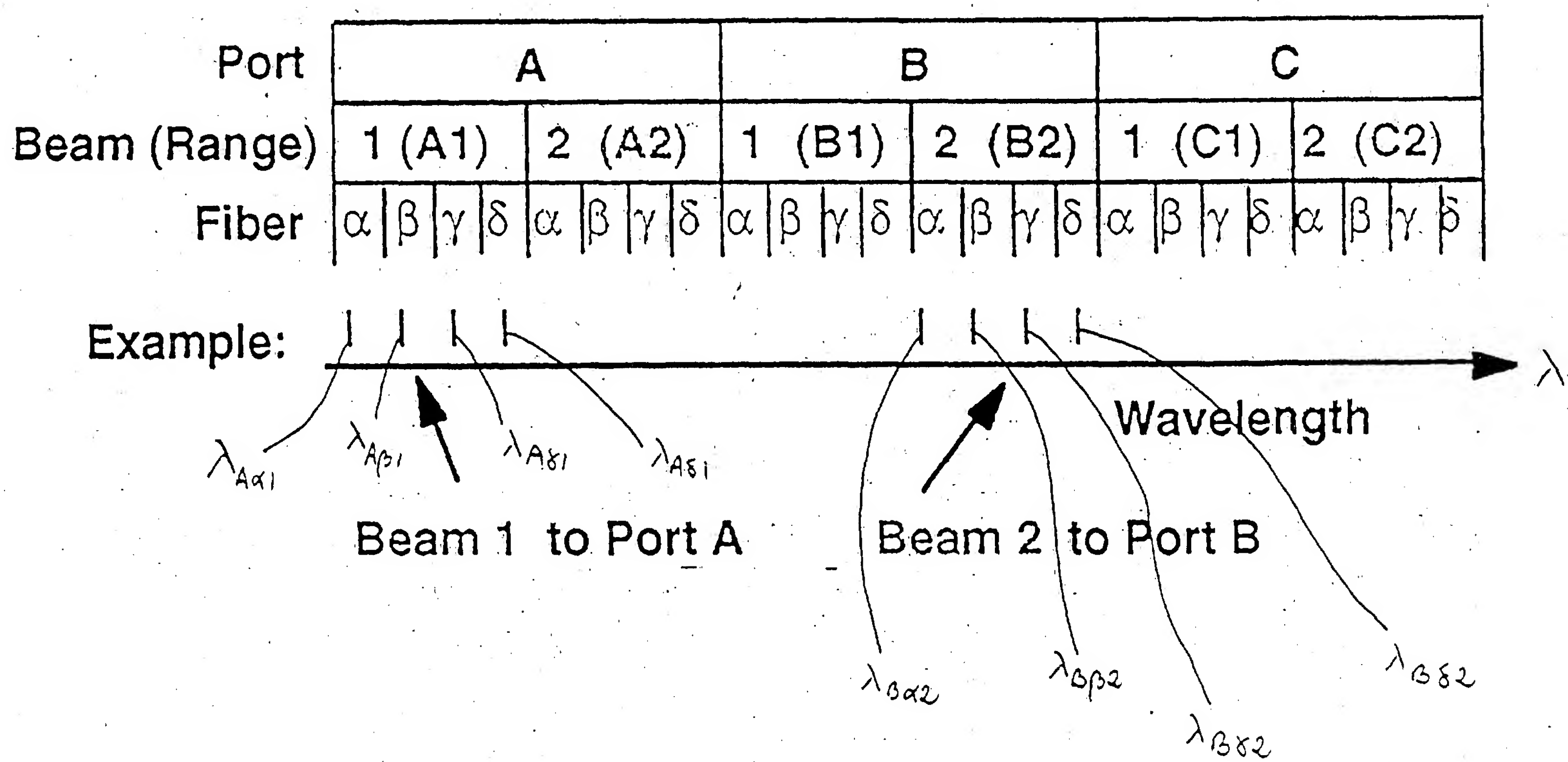

Port
A
B
C
Beam (Range)
1 (A1)
2 (A2)
1 (B1)
2 (B2)
1 (C1)
2 (C2)
Fiber
α β γ δ α β γ δ α β γ δ α β γ δ α β γ δ α β γ δ
Example:
λ
Wavelength
$\lambda_{A\alpha 1}$
$\lambda_{A\beta 1}$
$\lambda_{A\gamma 1}$
$\lambda_{A\delta 1}$
Beam 1 to Port A
Beam 2 to Port B
$\lambda_{B\alpha 2}$
$\lambda_{B\beta 2}$
$\lambda_{B\gamma 2}$
$\lambda_{B\delta 2}$

Fig. 3b

Conceptual 1x3 WDM Operation

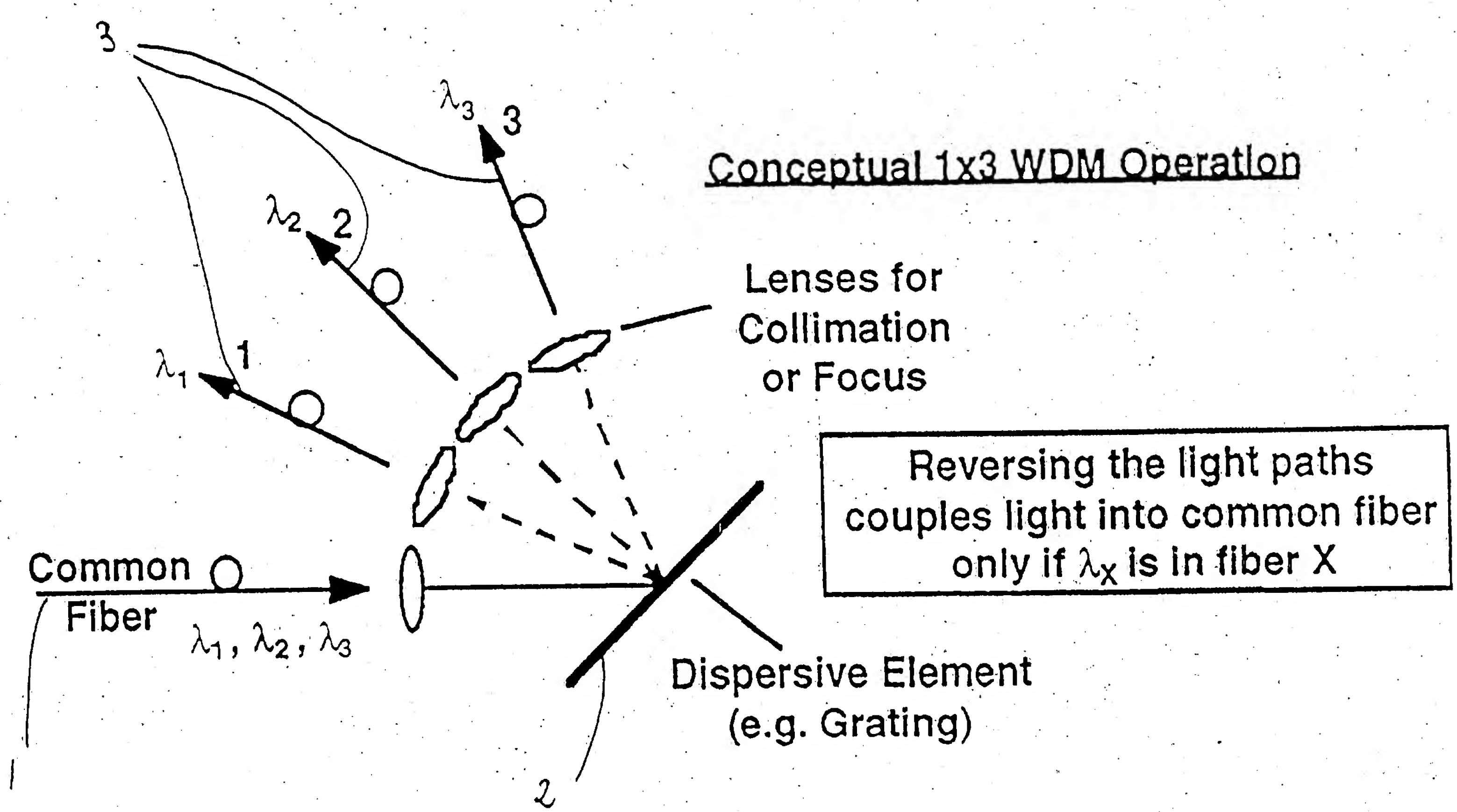
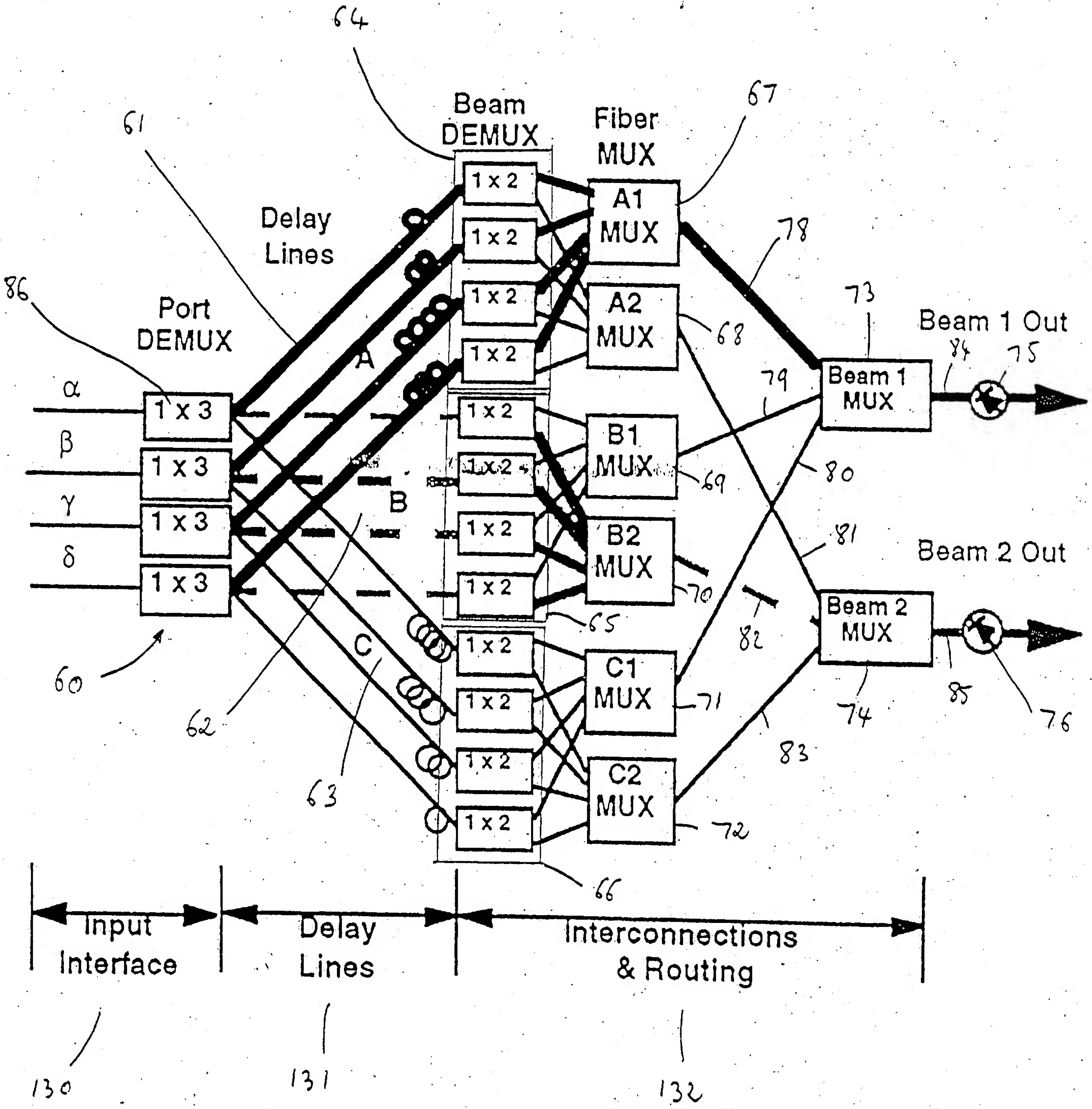


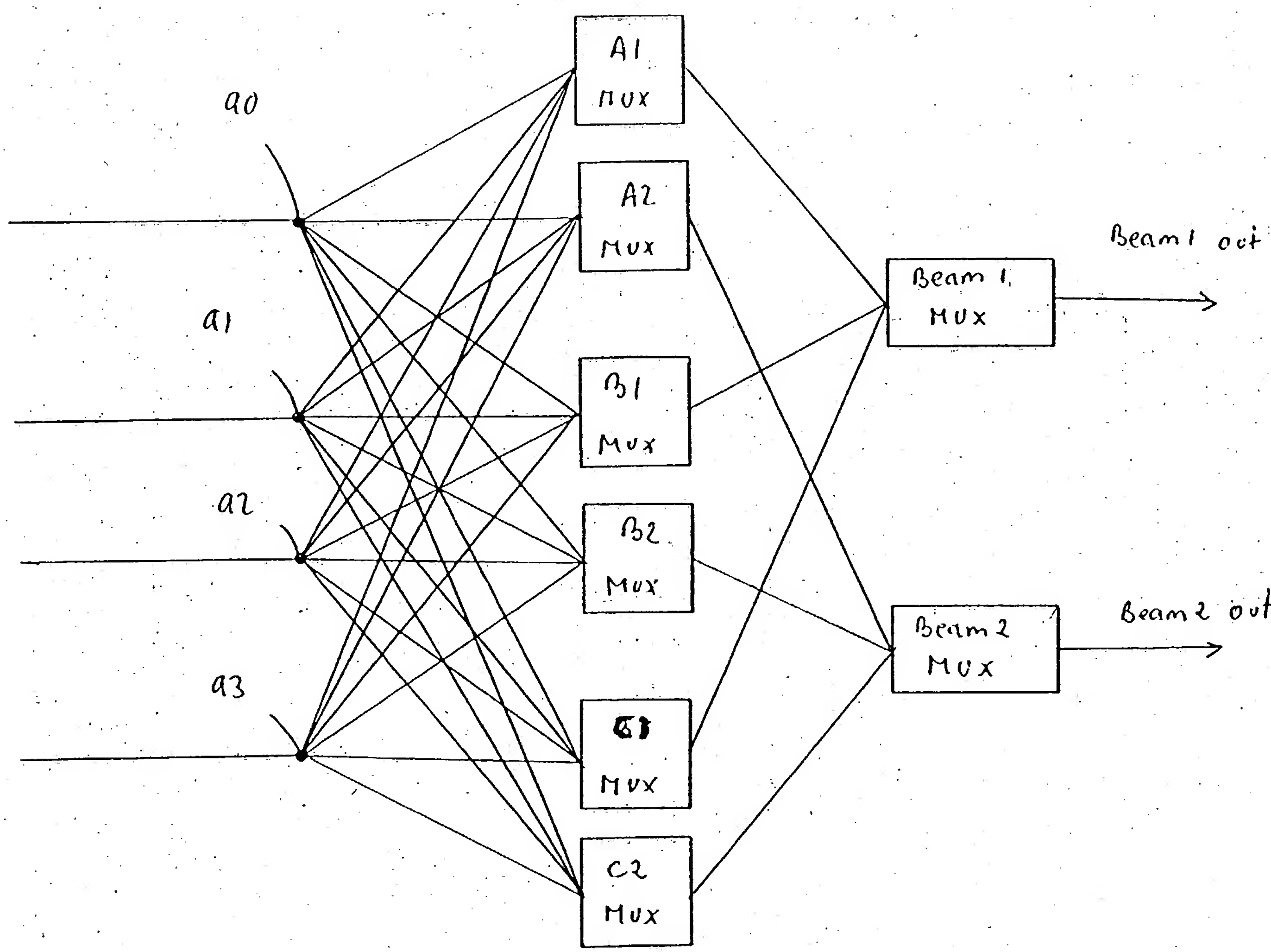
Fig. 4

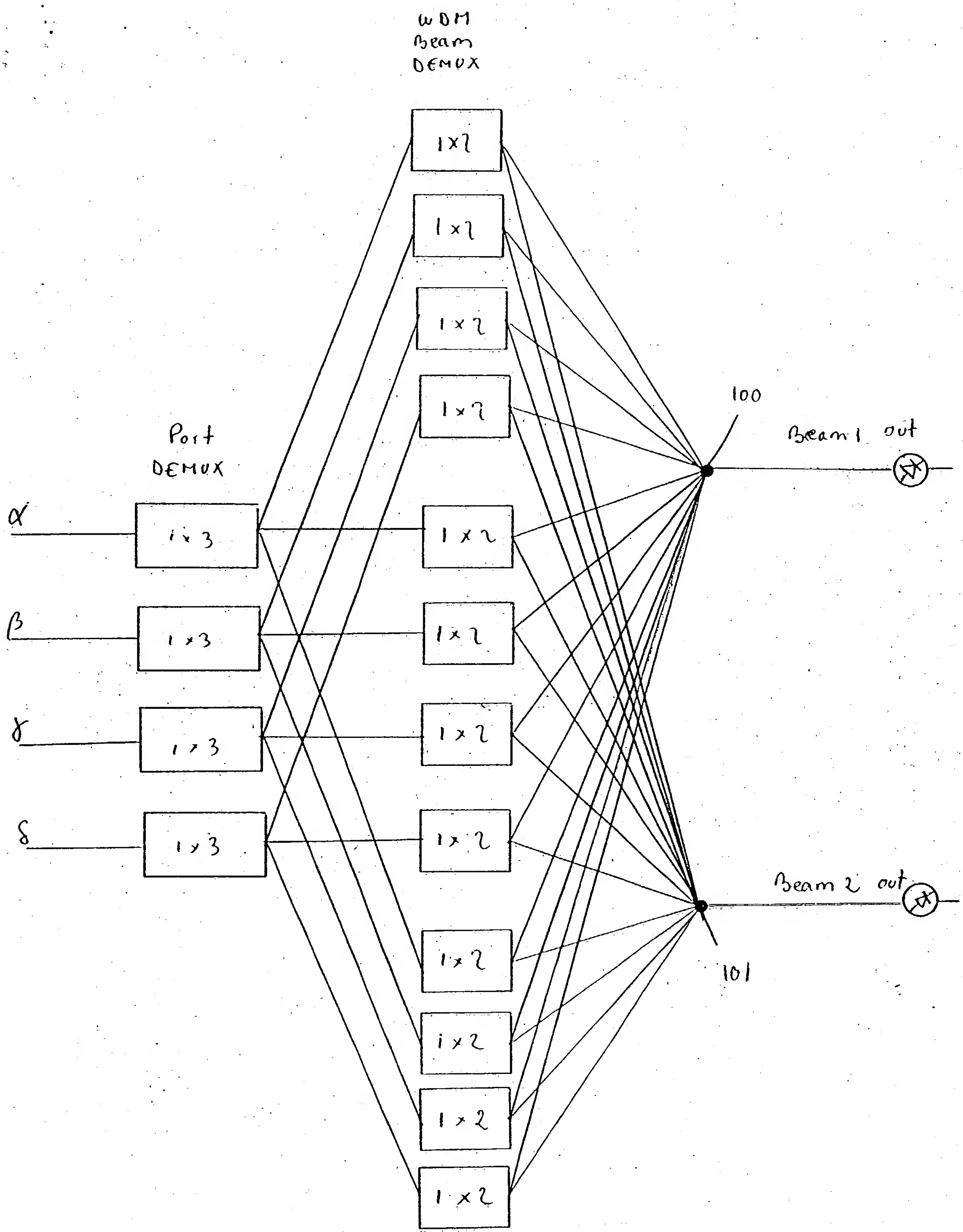
Fig. 5



Port DEMUX
Delay Lines
Beam DEMUX
Fiber MUX
1 x 3
1 x 2
A1 MUX
A2 MUX
B1 MUX
B2 MUX
C1 MUX
C2 MUX
Beam 1 MUX
Beam 2 MUX
Beam 1 Out
Beam 2 Out
A
B
C
α
β
γ
δ
Input Interface
Delay Lines
Interconnections & Routing
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
78
79
80
81
82
83
84
85
86
130
131
132

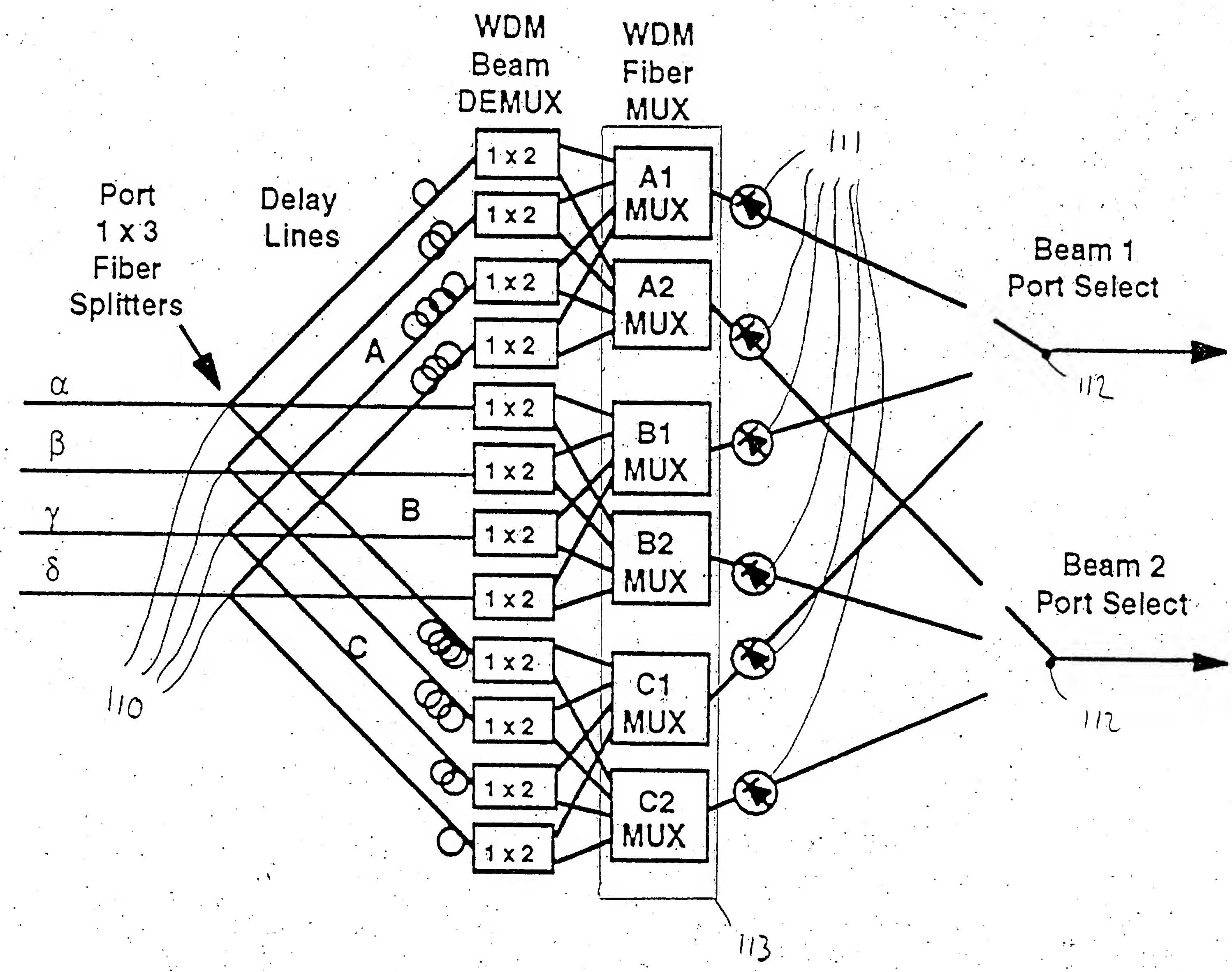
Fig. 6


a0
a1
a2
a3
A1
MUX
A2
Mux
B1
Mux
B2
Mux
Mux
C2
Mux
Beam 1
MUX
Beam 2
MUX
Beam1 out
Beam2 out



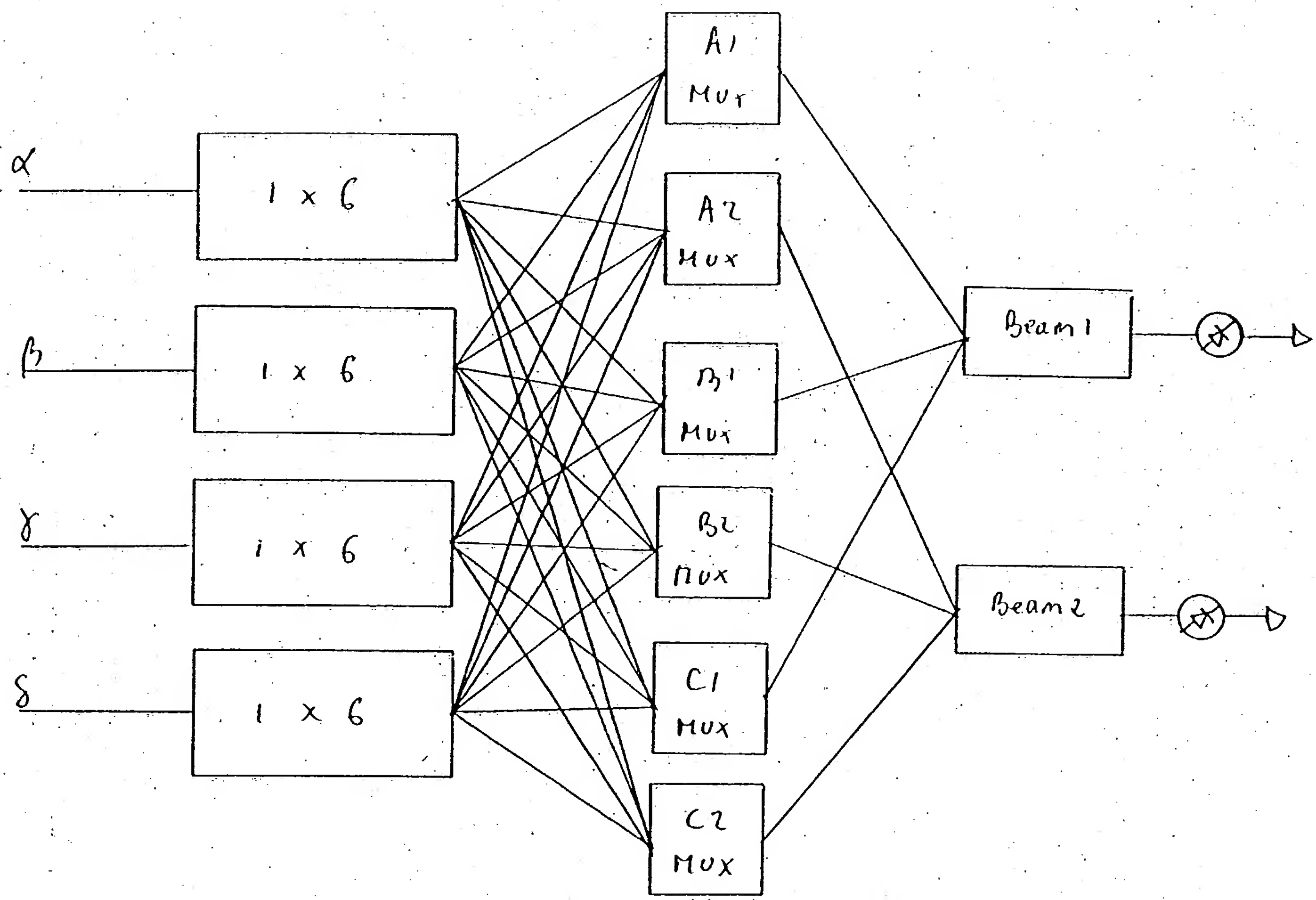
WDM
Beam
DEMUX
Port
DEMUX
α
β
γ
δ
1x3
1x3
1x3
1x3
1x2
1x2
1x2
1x2
1x2
1x2
1x2
1x2
1x2
1x2
1x2
1x2
100
101
Beam 1 out
Beam 2 out

Fig. 7



WDM
Beam
DEMUX
WDM
Fiber
MUX
Port
1 x 3
Fiber
Splitters
Delay
Lines
1 x 2
A1
MUX
A2
MUX
B1
MUX
B2
MUX
C1
MUX
C2
MUX
A
B
C
α
β
γ
δ
Beam 1
Port Select
Beam 2
Port Select
110
111
112
113

Fig. 8



α
β
γ
δ
1 x 6
1 x 6
1 x 6
1 x 6
A1 Mux
A2 Mux
B1 Mux
B2 Mux
C1 Mux
C2 Mux
Beam 1
Beam 2

Fig. 9

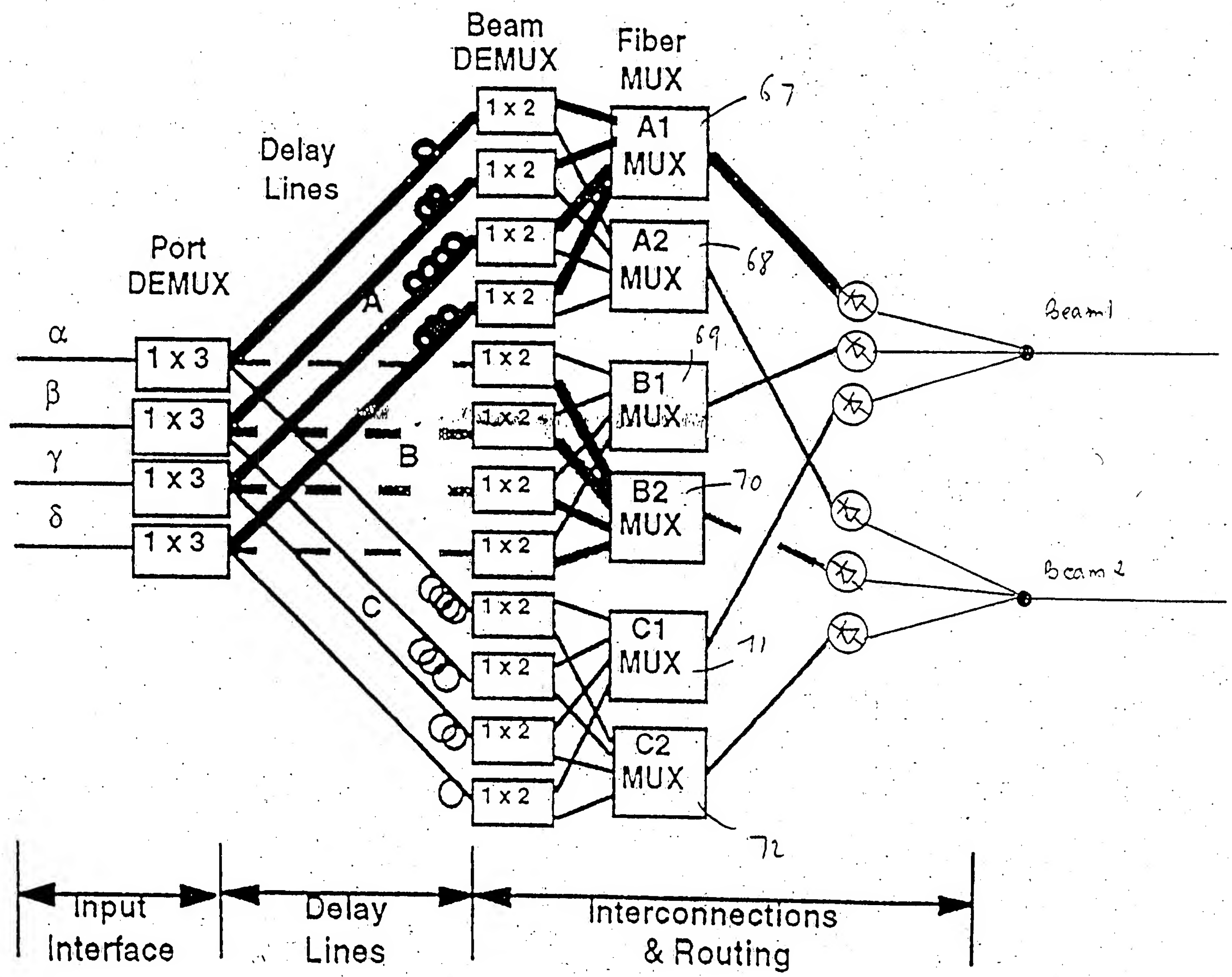

Beam
DEMUX
Fiber
MUX
Delay
Lines
Port
DEMUX
α
β
γ
δ
1 x 3
1 x 3
1 x 3
1 x 3
A
B
C
1 x 2
A1
MUX
A2
MUX
B1
MUX
B2
MUX
C1
MUX
C2
MUX
67
68
69
70
71
72
Beam 1
Beam 2
Input
Interface
Delay
Lines
Interconnections
& Routing

Fig. 10

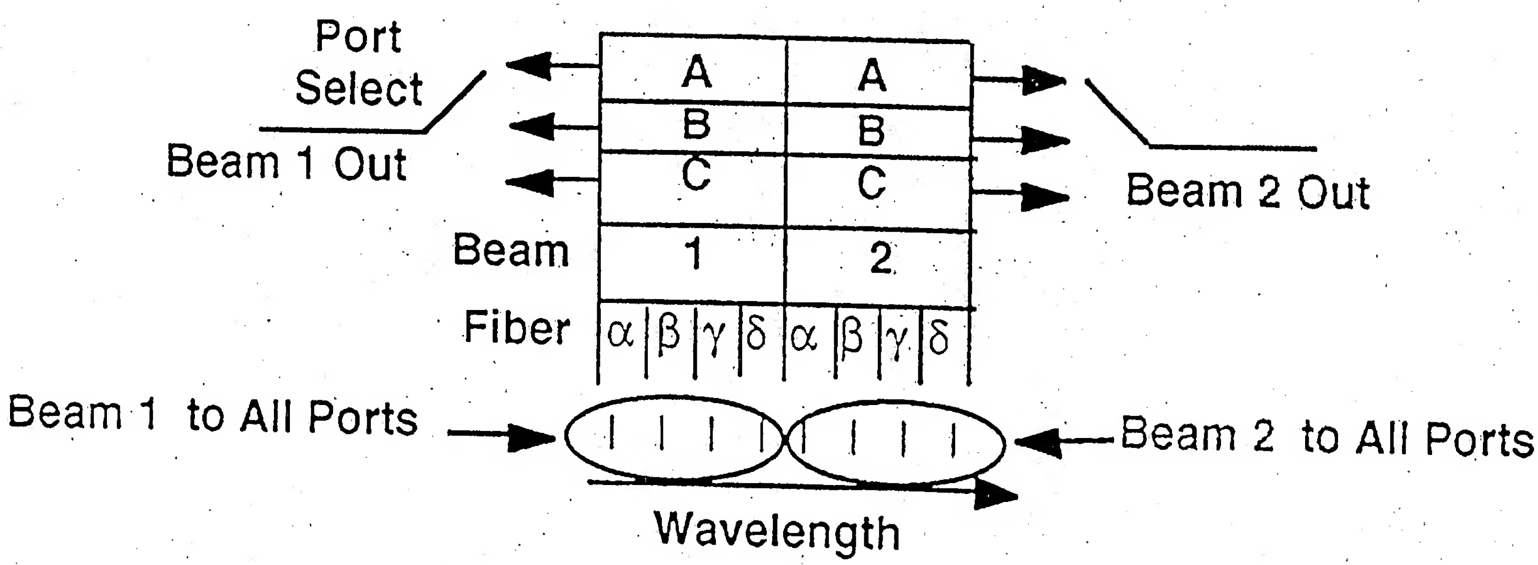

Port
Select
Beam 1 Out
A
B
C
A
B
C
Beam 2 Out
Beam
1
2
Fiber
α
β
γ
δ
α
β
γ
δ
Beam 1 to All Ports
Beam 2 to All Ports
Wavelength

Fig. 11

Fiber Connections in 2-D Network Switched Delay Lines
(Fiber Rotman Lens)

Port Connections for
One Fiber in Array

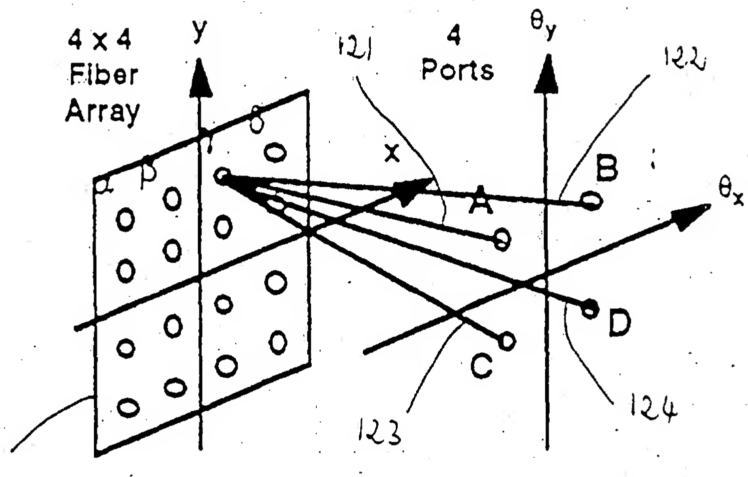


Fig. 12a

Connections to Fiber Array
for One Rotman Port

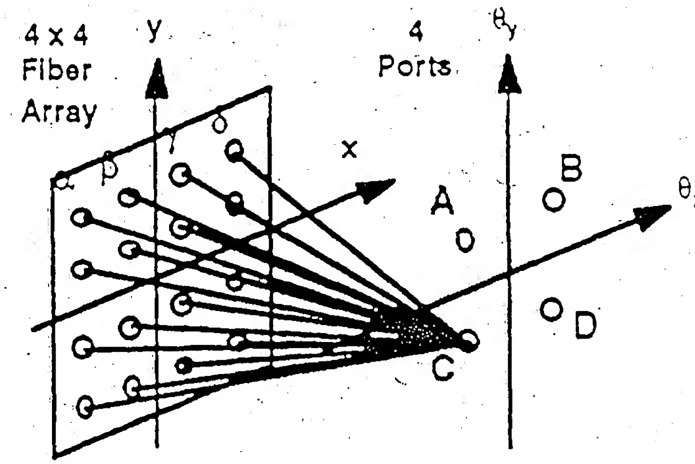


Fig. 12b

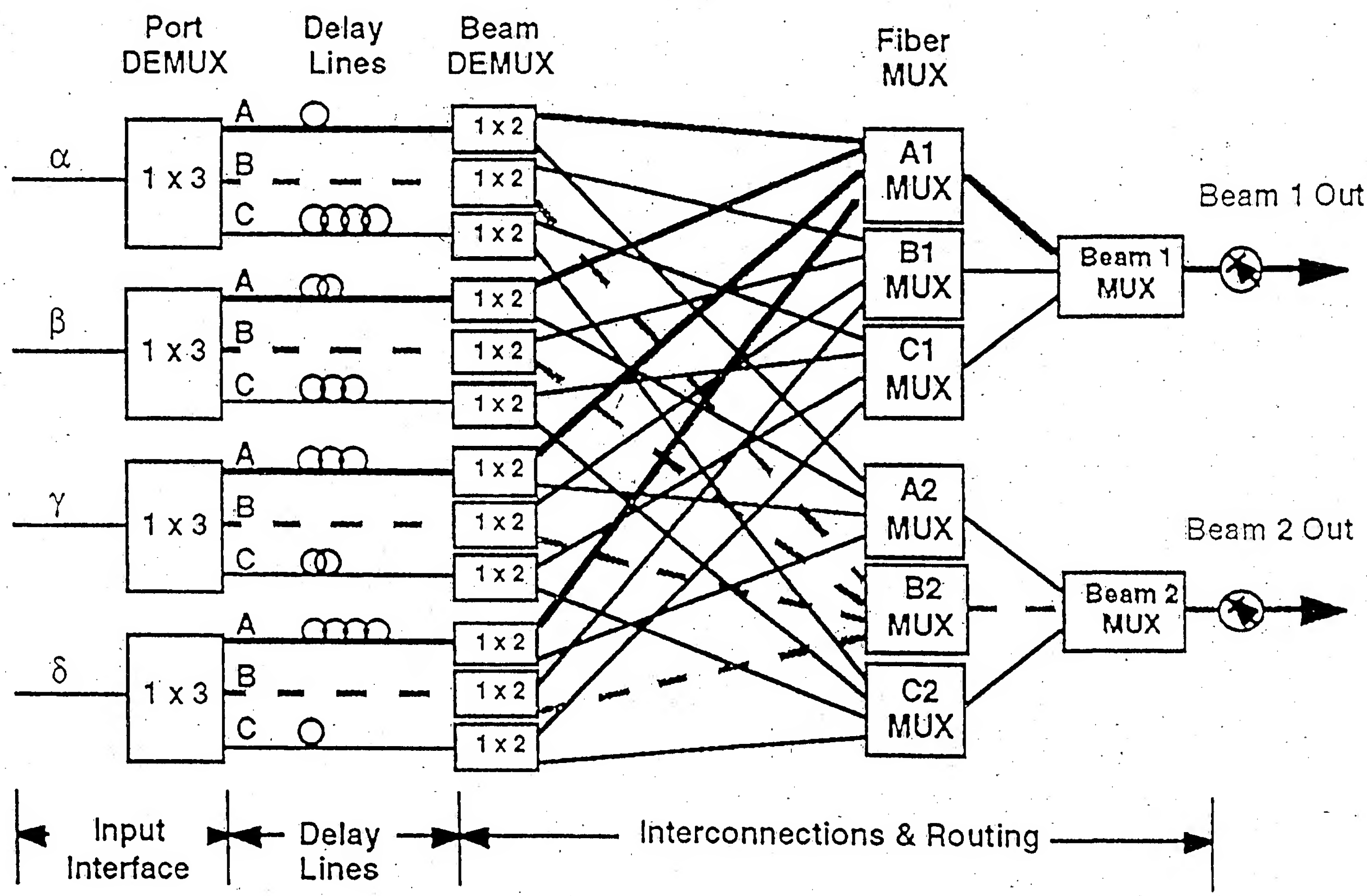
For a given port, the delay paths differ by ΔL_x and ΔL_y while passing from fiber to fiber in the array

$\Delta L_x=(Dv/c)\sin\theta_x$, $\Delta L_y=(Dv/c)\sin\theta_y$

D = Antenna element spacing
v = Light velocity in delay line
c = Light velocity in vacuum
θ_x, θ_y = x, y components of delay line scan angle

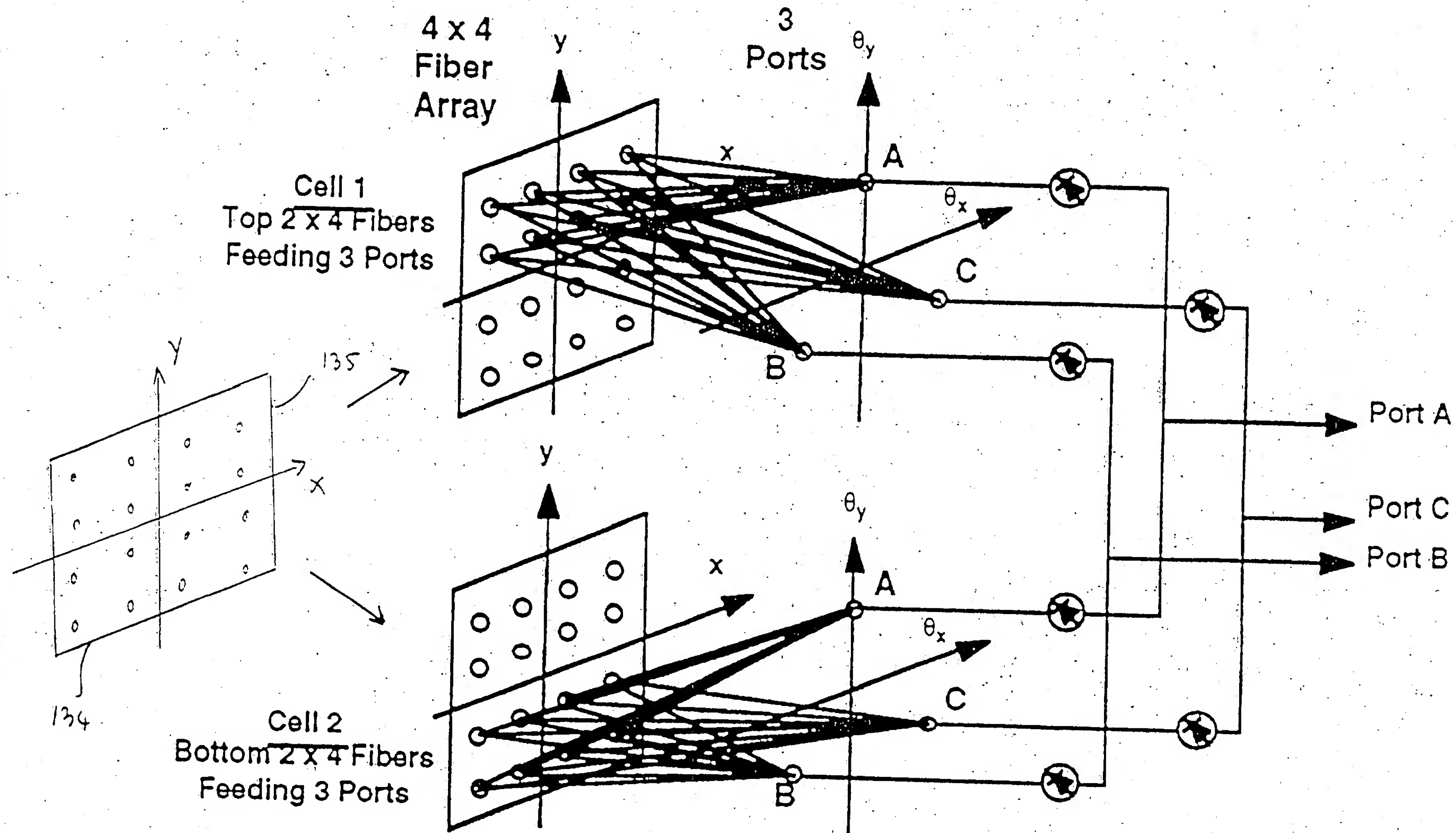
125

Fig. 12



Port DEMUX
Delay Lines
Beam DEMUX
Fiber MUX
α
β
γ
δ
1 x 3
A
B
C
1 x 2
A1 MUX
B1 MUX
C1 MUX
A2 MUX
B2 MUX
C2 MUX
Beam 1 MUX
Beam 2 MUX
Beam 1 Out
Beam 2 Out
Input Interface
Delay Lines
Interconnections & Routing

Fig. 13



4 x 4
Fiber
Array
3
Ports
Cell 1
Top 2 x 4 Fibers
Feeding 3 Ports
Cell 2
Bottom 2 x 4 Fibers
Feeding 3 Ports
y
x
A
B
C
135
134
Port A
Port C
Port B

Fig. 14

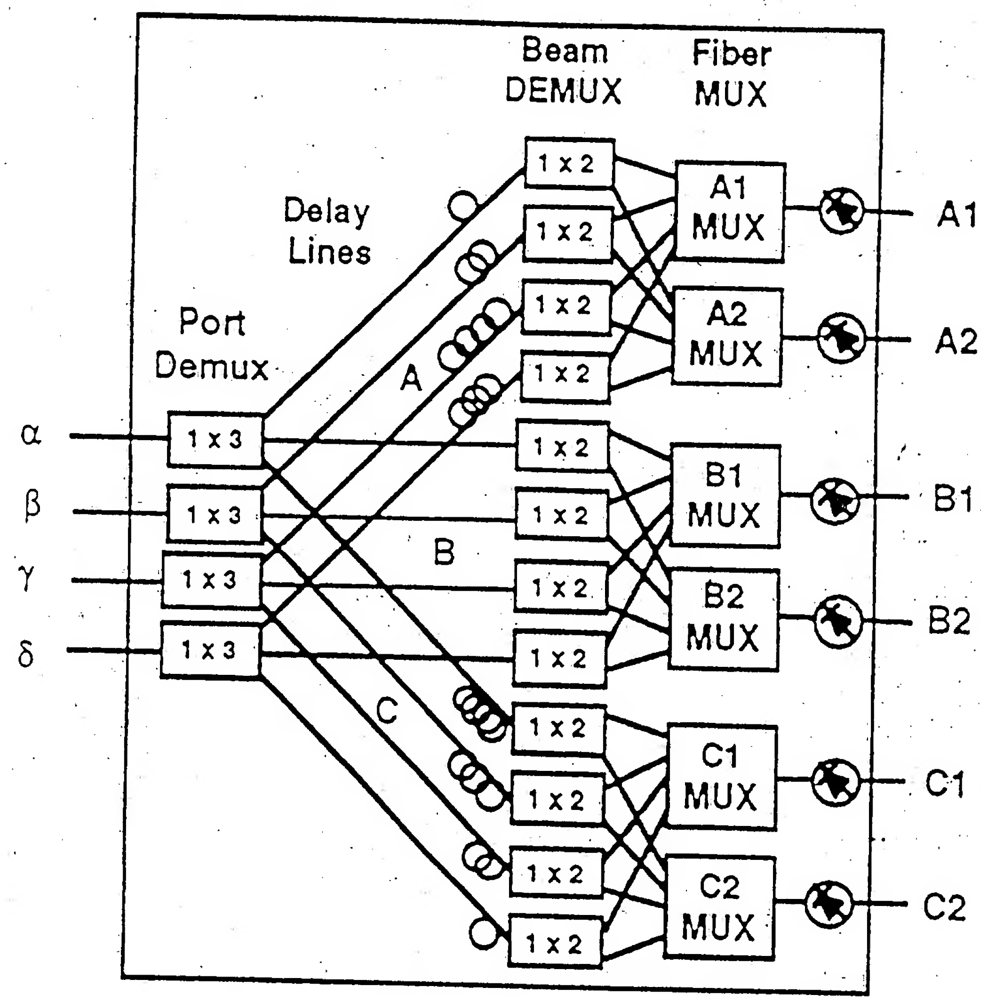


Fig. 15a

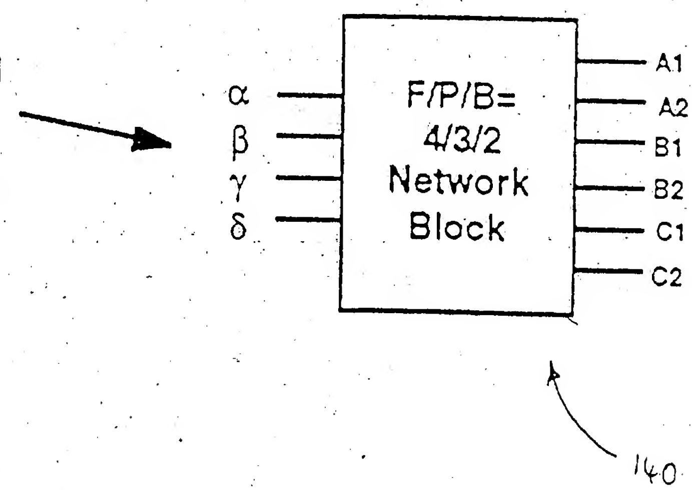
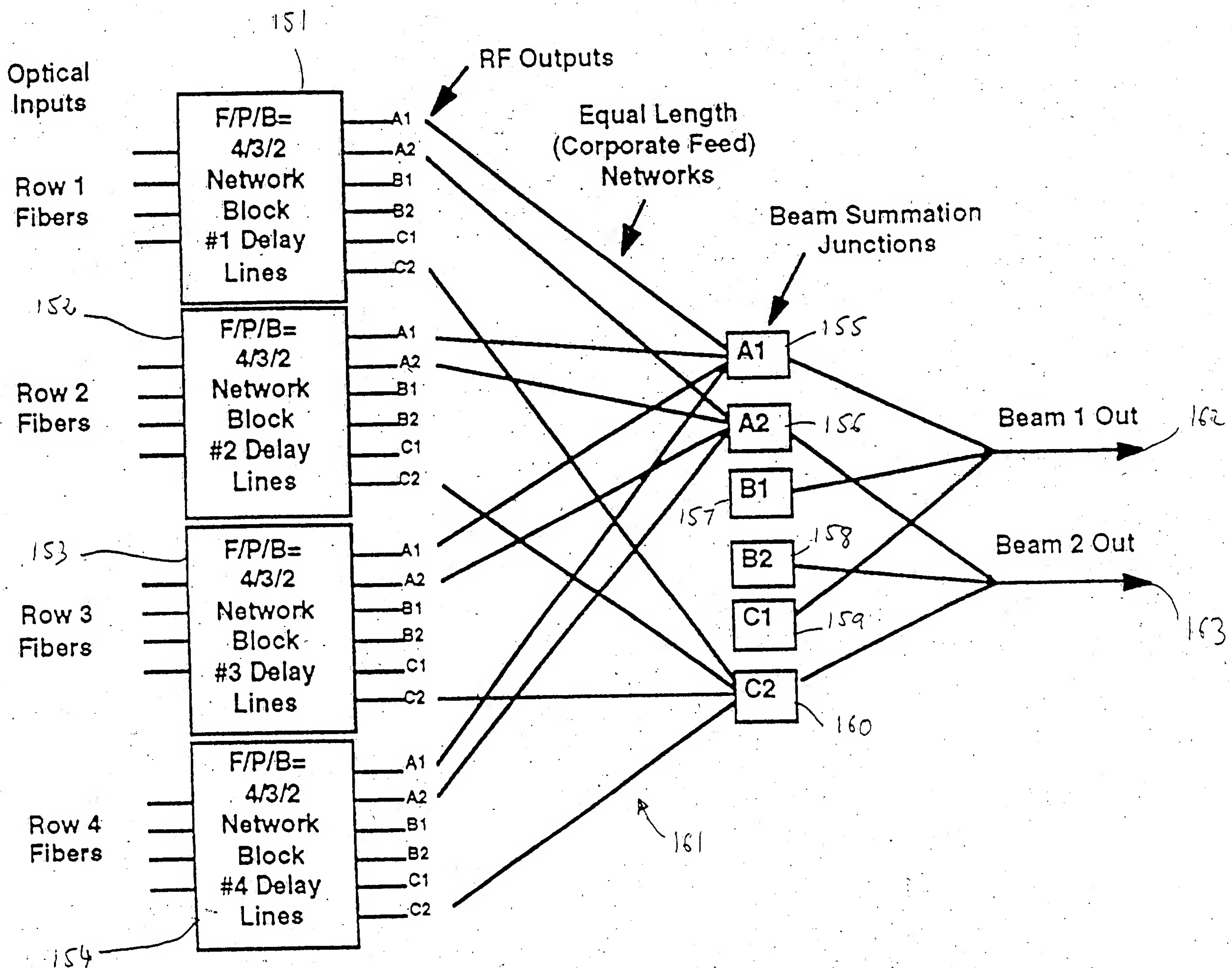


Fig. 15b



151
Optical Inputs
Row 1 Fibers
F/P/B= 4/3/2 Network Block #1 Delay Lines
A1
A2
B1
B2
C1
C2
RF Outputs
Equal Length (Corporate Feed) Networks
Beam Summation Junctions
152
Row 2 Fibers
F/P/B= 4/3/2 Network Block #2 Delay Lines
153
Row 3 Fibers
F/P/B= 4/3/2 Network Block #3 Delay Lines
Row 4 Fibers
F/P/B= 4/3/2 Network Block #4 Delay Lines
154
155
156
157
158
159
160
161
Beam 1 Out
162
Beam 2 Out
163

Fig. 16

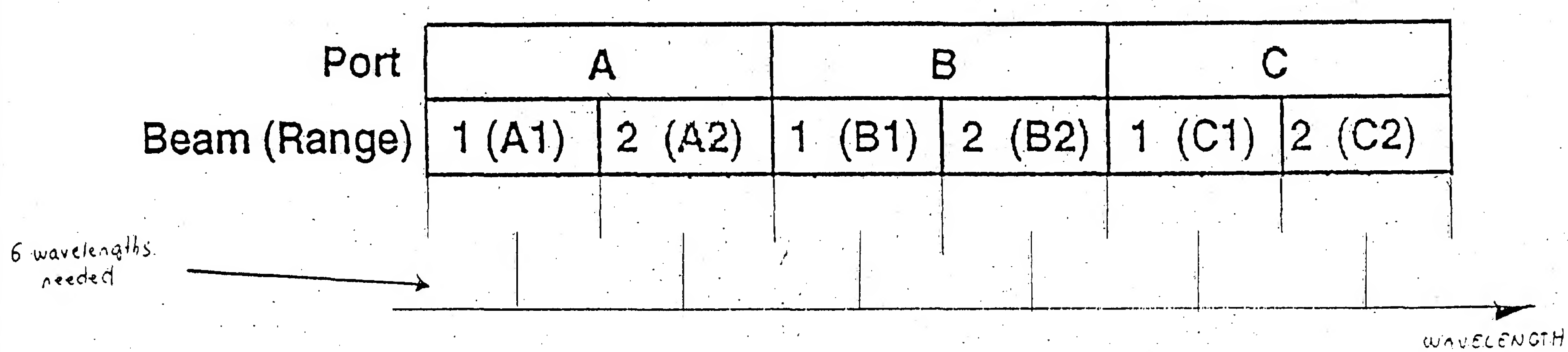

Port
A
B
C
Beam (Range)
1 (A1)
2 (A2)
1 (B1)
2 (B2)
1 (C1)
2 (C2)
6 wavelengths needed
WAVELENGTH

Fig. 17

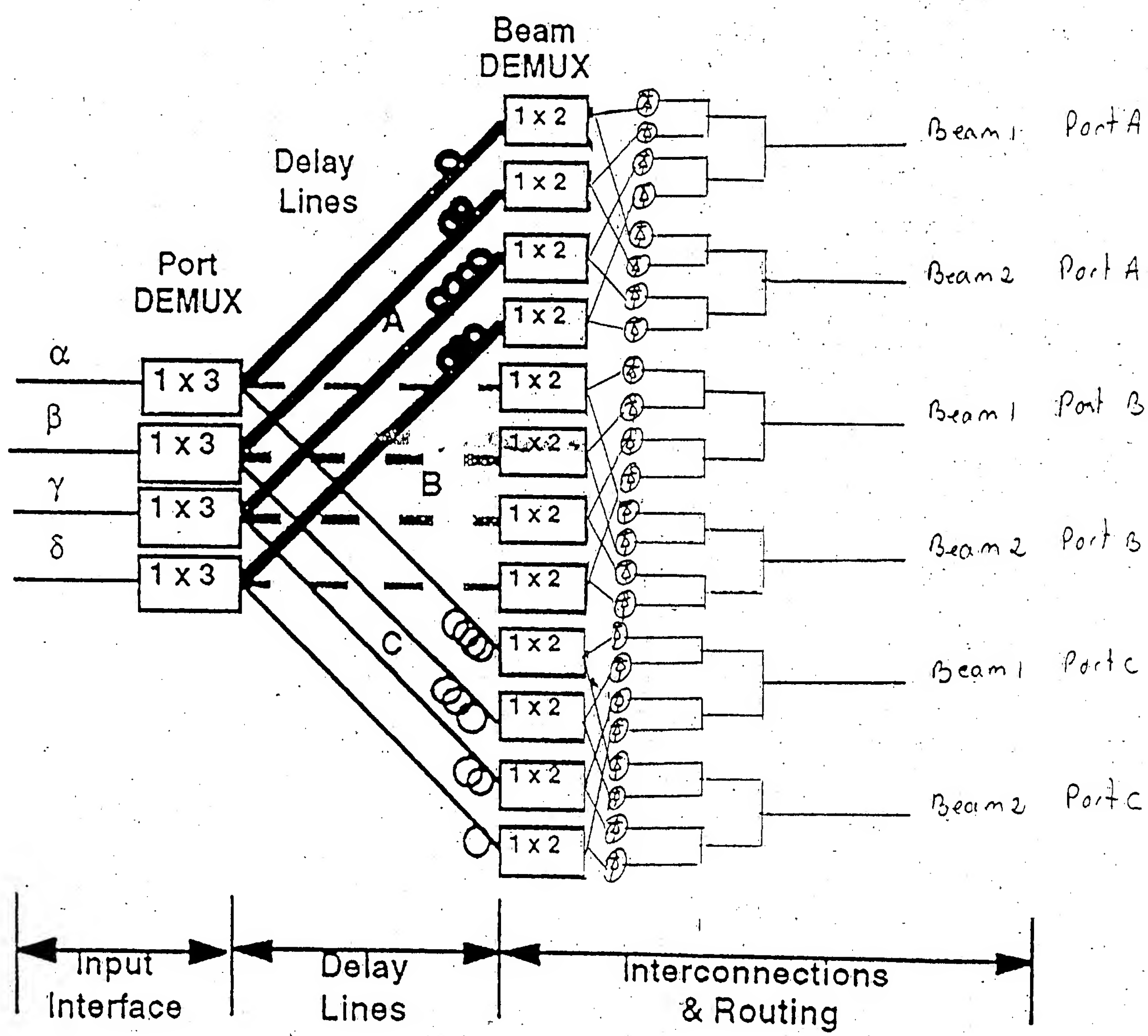

Beam DEMUX
Delay Lines
Port DEMUX
α
β
γ
δ
1 x 3
1 x 2
A
B
C
Beam 1 Port A
Beam 2 Port A
Beam 1 Port B
Beam 2 Port B
Beam 1 Port C
Beam 2 Port C
Input Interface
Delay Lines
Interconnections & Routing

Fig. 18

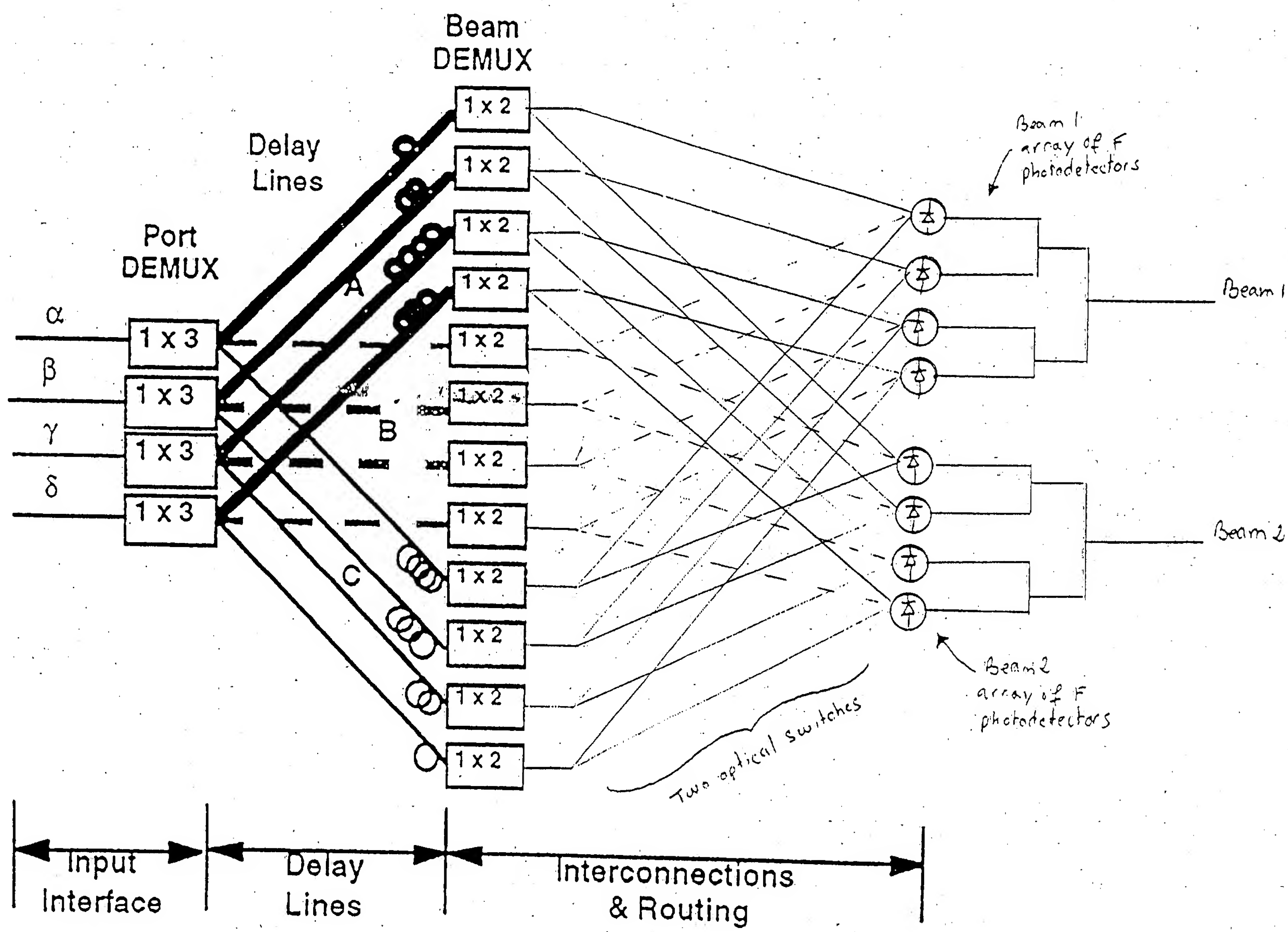

Beam DEMUX
Delay Lines
Port DEMUX
α
β
γ
δ
1 x 3
1 x 2
A
B
C
Beam 1 array of F photodetectors
Beam 1
Beam 2
Beam 2 array of F photodetectors
Two optical switches
Input Interface
Delay Lines
Interconnections & Routing

Fig. 19